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POSTRELEASE RECOVERIES OF HAND FED VERSUS DEMAND FED SEA-RUN CUTTHROAT TROUT, AND POSTRELEASE SURVIVALS OF SEA-RUN CUTTHROAT REARED IN A POND FOR VARIOUS DURATIONS

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Abstract

An experiment that compared the smolt-to-adult survival of Cowlitz Hatchery sea-run cutthroat that were hand-fed versus demand fed showed that for three years of release demand fed fish outperformed hand-fed fish by an average of 9.5%, not statistically different.

An experiment comparing the smolt-to-adult survival of hatchery sea-run cutthroat that were placed in a rearing pond for months prior to release versus one month prior to release showed that an average of 20% more fish returned which had been reared in the pond for months versus one month prior to release.

Hand vs Demand Feeding

At salmonid hatcheries, two common methods of delivering feed to fish are hand-feeding and demand feeders. Advocates of hand-feeding like monitoring fish health and vigor while feeding. Users of demand feeders often claim savings in feed and labor costs (Statler 1982; Kindschi 1984; Tipping et al. 1986; Alanara 1992; Aloisi 1994). Fish behaviors differ in the two feeding methods; hand-fed fish are attracted to the person delivering the feed while fish with demand feeders often some fright response to people moving along the rearing vessel. This behavior difference might influence post-release survivals. However, no literature was found comparing the post-release survival of fish reared on the two methods or any other feed delivery system. This experiment was conducted to compare the post-release survival of fish reared by hand-feeding compare to those on demand feeders.

Methods

At the Cowlitz Trout Hatchery in October 1996, 1997, and 1998, sea-run cutthroat trout juveniles weighing about 40-50 g each were marked and randomly assigned to one of two raceways, each containing about 25,000 fish. Thereafter, fish in one raceway were fed ad libitum with dry feed using four Babington demand feeders per raceway. Fish in the second raceway were fed by hand three to four times per day.

The raceways were 6.1 x 30.3 x 0.9 m with a water flow of about 74 L/s of re-used well water mixed with river water. The raceways also had six strands of wire placed lengthwise above the raceways to deter avian predators.

The fish were marked with a left ventral fin-clip in combination with a magnetic wire tag placed in the left or right cheek in 1996 and 1998. In 1997, the fish were marked with only a wire tag in the left or right cheek.

Both groups were released concurrently in late April of each year. At release, about 300 smolts from each group were measured for fork length (cm) and 50 fish were weighed (g) so condition factor ($K=[10^2 \text{weight,g}]/[\text{length,cm}]^3$) could be determined. Several hundred fish were sampled for the presence of a wire tag with a wand detector (Northwest Marine Technology, Shaw Island, Washington). The appropriate tag retention rate (range 71-90%) was applied to the number of fish released to determine the number of tagged fish released in each group. The release site was about 109 km upstream on the Columbia River, 68 km up the Cowlitz River, and 1 km up Blue Creek; the hatchery rack was about 0.6 km above the release site.

Recoveries of tagged adult cutthroat trout were obtained with occasional creel checks of recreational anglers from August through October from 1996 through 1999. In addition, all cutthroat trout entering the Cowlitz Trout Hatchery in November through January were examined for tags. A ventral fin of fish returning to the hatchery was excised so they would not be counted in a subsequent year or the fish were moved to a non-anadromous water.

Chi-square ($\underline{P}=0.05$) was used to compare the number of fish returned from the two groups of fish. Student's t-test ($\underline{P}=0.05$) was used to test for differences in length and condition factor of smolts at release.

Results

At release, a 0.3 cm length difference for the 1996 release was significantly greater for demand than hand-fed fish ($t= 3.73$, $p<0.05$) and a 0.7 cm length difference for the 1997 release of demand-fed fish was significantly greater than hand-fed fish ($t=5.50$, $p<0.05$) (Table 1). The 1998 release was statistically similar. However, prior work has shown that the lengths at release for all three years observed herein would be biologically similar for Cowlitz Hatchery sea-run cutthroat (Tipping 1986; Tipping and Blankenship 1993).

A total of 1,004 marked adult fish were recovered; the hatchery rack accounted for 96.0% while 4.0% were recovered in the sport fishery. Final recoveries for the 1998 release will occur this winter but they are not expected to change overall results. Recoveries of the 1998 release were two to three times greater than the 1996 and 1997 releases.

For the 1996 release, adult recoveries of demand-fed fish were 38% greater than hand-fed fish, a significant difference ($X^2=4.34$, $p<0.05$). For the 1997 release, recoveries of demand-fed fish outperformed hand-fed fish by 24% but were not significantly different. For the 1998 release, hand-fed fish outperformed demand-fed fish by 2%, statistically similar. For all releases combined, 0.92% of demand-fed fish were recovered versus 0.84% for hand-fed fish, a 9.5% increase, which was not significantly different.

Discussion

Results from this experiment were not compelling: demand-fed fish had an overall increase in adult returns of about 10% but only statistically showed benefit in one of three years of release. Although a 10% increase would certainly be a welcome increase to adult return rates, other feeding methods need to be developed that might increase adult survivals (Wiley et al. 1993; Maynard et al. 1995). Conversely, unless a better feeding method that increases survival is developed, hand or demand feeding appear to produce fish with similar survivals.

Table 1. Length, weight, condition factor and adult returns of hand and demand fed sea-run cutthroat.

Release year	1996		1997		1998		Total	
	Hand	Demand	Hand	Demand	Hand	Demand	Hand	Demand
Mean Length (cm)	21.9	22.2	22.3	23.0	24.3	24.4		
Mean K	1.09	1.08	1.05	1.07	1.11	1.13		
N=	300	300	304	304	300	300		
No. tagged fish	17,452	18,637	19,386	17,973	21,089	19,862	57,927	56,472
Adult Returns								
First year	67	98	106	130	287	264		
Second year	3	5	24	20	NA	NA		
Total	70	103	130	150			487	517
Percent	0.40	0.55	0.67	0.83	1.36	1.33	0.84	0.92

Pond Duration Study

A common rearing practice at many salmonid hatcheries is to place juvenile fish from concrete raceways into large rearing ponds in February or March prior to spring release. Ponds are thought to improve the quality of fish by exposing them to a more natural environment before liberation (Piper et al. 1982; Maynard et al. 1995). Tipping (1998) reported that sea-run cutthroat trout reared in a pond had 160% of the adult survival of fish produced from concrete raceways. However, it is not known if extended duration of pond exposure increases post-release survival. This experiment was conducted to determine if sea-run cutthroat trout placed in a pond for a month prior to release have the same survival of those reared for a longer time in a pond.

Methods

At the Cowlitz Trout Hatchery in October 1996, 1997, and 1998, sea-run cutthroat trout juveniles weighing about 40-50 g each were marked and randomly assigned to one of two raceways, each containing about 20,000 fish. The fish were marked with a right ventral fin-clip in combination with a magnetic wire tag placed in the left or right cheek in 1996 and 1998. In 1997, the fish were marked with a wire tag in the snout or the nape of the neck.

The concrete raceways were 6.1 x 30.3 x 0.9 m with a water flow of about 74 L/s of re-used well water mixed with river water. Fish were fed ad libitum with dry feed using four Babington demand feeders per raceway. The raceways also had six strands of wire placed lengthwise above the raceways to deter avian predators.

One raceway of fish was moved to a gravel/earth bottom rearing pond in October 1995 at 28 g, December 1996 at 60 g and January 1998 at 90 g for the three release years, respectively. The second raceway of fish was placed in the pond in March at about 83 g in 1996, 105 g in 1997, and 125 g in 1998. In addition to tagged cutthroat, untagged cutthroat and steelhead were also placed in the pond in October to January. About 114,000 cutthroat and 162,000 steelhead were released from the pond in 1996 (22,600 kg), 120,000 cutthroat and 117,000 steelhead in 1997 (19,300 kg), and 80,000 cutthroat and 44,000 steelhead in 1998 (17,800 kg).

For the 1996 release, rearing pond dimensions were 440 x 50 x 2 m, thereafter reduced to 280 x 50 x 2 m for the 1997 and 1998 releases. Pond inflow was about 227 L/s re-used well water mixed with river water. Fish were fed ad libitum with eight Babington demand feeders in 1996 and six feeders in 1997 and 1998 stationed around the pond. The pond was equipped anti-predator exclusion fencing on the ground, an electrical fence, overhead wires, plus U.S. Department of Agriculture personnel were present to haze predators at the hatchery.

Both groups were released concurrently from the pond in late April to early May. At release, about 300 smolts from each group were measured for fork length (cm) and 50 fish were weighed (g) so condition factor ($K=[10^2 \text{weight,g}]/[\text{length,cm}]^3$) could be determined. Just before fish were moved from the raceway to the rearing pond, several hundred fish were sampled for the presence of a wire tag with a wand detector (Northwest Marine Technology, Shaw Island, Washington). The appropriate tag retention rate (range 78-89%) was applied to the number of fish released to determine the number of tagged fish released in each group. The release site was about 109 km upstream on the Columbia River, 68 km up the Cowlitz River, and 1 km up Blue Creek; the hatchery rack was about 0.6 km above the release site.

Recoveries of tagged adult cutthroat trout were obtained with occasional creel checks of recreational anglers from August through October from 1996 through 1999. In addition, all cutthroat trout entering the Cowlitz Trout Hatchery in November through January were examined for tags. A ventral fin of fish returning to the hatchery was excised so they would not be counted in a subsequent year.

Chi-square ($\underline{P}$=0.05) was used to compare the number of fish returned from the two groups of fish. Student's t-test ($\underline{P}$=0.05) was used to test for differences in length and condition factor of smolts at release.

Results

At release, lengths of both groups of fish were similar while earlier ponded fish tended to have slightly greater condition factors (Table 2). A total of 2,392 adult fish from this experiment were recovered; the hatchery rack accounted for 98.7% while only 1.3% were recovered in the sport fishery. Recoveries of the 1998 release were three to nine times greater than the 1996 and 1997 releases.

For the 1996 release, adult recoveries of the October ponded fish were 11% greater than March ponded fish, statistically similar. For the 1997 release, recoveries of the December ponded fish outperformed the March ponded fish by 44% (X^2=15.38, p<0.005). For the 1998 release, recoveries of January ponded fish were 7% greater than March ponded fish, statistically similar. For all releases combined, 2.4% of early ponded fish were recovered versus 2.0% for March ponded fish, a 20% increase which was significantly different (X^2=14.69, p<0.005).

Table 2. Length, K-factor, number of tagged fish released and adult returns as part of a pond rearing duration study.

Year	1996		1997		1998	
Month Ponded	October	March	December	March	January	March
Mean length (cm)	21.6	21.9	22.5	22.4	24.8	24.8
Mean K-factor	0.93	0.90	1.01	0.98	1.02	1.00
N=	300	300	296	296	300	300
No. marked fish released	17,905	14,602	19,818	20,281	19,797	16,582
Adult Returns						
First year	86	63	254	182	992	775
Second year	5	4	20	13	NA	NA
Total	91	67	274	195		
Percent	0.51	0.46	1.38	0.96	5.01	4.67

Discussion

Results from this experiment indicate that longer exposure times to semi-natural rearing ponds are generally better for post-release survival than short exposures. However, results were statistically significant only for the 1997 release and when all releases were combined. Unfortunately, results did not show an increasing survival trend as pond rearing time increased; the October group (1996) had only an 11% improvement compared to a 44% improvement for the December group (1997). Overall, this study suggests that hatchery managers should move fish from raceways to ponds early if possible.

Also, recoveries of pond-reared sea-run cutthroat trout in this study averaged 2.2% while those from concrete raceways for the hand versus demand feeding study was 0.86%, a ratio of 2.6:1. This is considerably greater than that reported by Tipping (1998) with an improvement of 1.6:1 for a previous study comparing survivals of fish reared in a raceway versus a rearing pond.

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THE EFFECTS OF GROWTH RATE AND A LOW FAT DIET ON THE INCIDENCE OF SEXUAL MATURATION IN 1^+ AGE MALE SPRING CHINOOK SALMON

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Abstract

The purpose of our experiment was to determine the effects of growth rate and a low fat diet on the incidence of early sexual maturation in male spring chinook salmon (Oncorhynchus tshawytscha). Fish (0.5 g initial weight) were fed a practical low fat diet (7% fat, 54% protein, 19.7 KJ/g) at six feeding levels (100, 88, 76, 64, 52, or 40% of satiation) from February 1998 until July 1999. A commercial diet (BioOregon-grower: 21.8% fat, 49.9% protein, 22.1 KJ/g) was also fed at the 64% level. All diets were fed in duplicate (700 fish/tank). Fish were sampled at ca. monthly intervals to measure growth, proximate composition and state of sexual maturity. Fish weights at the end of the experiment were, respectively 336, 304, 286, 241, 203, 161 and 258g for the 100-40% ration groups and the commercial feed. Maturing males were significantly larger than nonmaturing males and females, which were similar in all treatments, from March 1999 until the end of the experiment. Whole body fat levels in fish fed the low fat diet at all feeding levels did not differ and remained between 2.5 and 5% from the start of the experiment until September 1998. Body fat levels then increased in these groups. Fish fed the commercial feed had fat levels which increased from first feeding, reached 8% in September 1998, and then continued to increase until May 1999. Maturing males in all treatments had significantly higher fat levels than nonmaturing males or females from January 1999 until the termination of the experiment in July 1999. The incidence of maturing males ranged from 66 to 93% and was significantly affected by feeding level. The relationship between feeding level and maturation, which was lowest in the 40% feeding level fish, highest in fish fed at the 76% level and lower again in fish fed at the 100% level was best described by a quadratic equation. Comparison of data for fish fed the commercial and experimental feeds indicates that body fat level had no effect on the incidence of maturation. Our next study will examine the effects of much lower growth rates (<100 g at 1^+) on male maturation.

INCREASED REARING DENSITIES IN HATCHERIES CAN INCREASE RUNS OF COLUMBIA RIVER SPRING CHINOOK SALMON

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Abstract

In 1988, Bonneville Power Administration funded a project at Willamette Hatchery to test the feasibility of using increased rearing densities in existing hatcheries to augment the runs of chinook salmon in the Columbia River Basin. Oxygen supplementation was used to permit increased rearing densities of juvenile chinook salmon without risking the production from poor water quality. Also included in the test were a series of raceways using a new design that incorporated a series of baffles to effect an automatic cleaning of the raceways (Boerson and Westers 1986).

At that time, a series of questions were proposed that the experiment was to answer:

1) Could increased rearing densities in a surface water hatchery result in increased production of adult chinook salmon?
2) Could the baffled raceways be used for rearing increased densities of fish while minimizing the time necessary for cleaning the raceways?
3) Will ammonia concentrations limit production from raceways with increased rearing densities?
4) Does oxygen provide cost-effective benefits for the high-density rearing of chinook salmon.

The experiment required a series of seven experimental raceways of different densities and conformations (Table 1). These experimental raceways were duplicated to account for possible raceway effects. Approximately 30,000 fish from each raceway were marked with adipose-fin clips and coded-wire tags. The fish were reared at Willamette Hatchery and hauled to the Willamette River below Dexter Dam in late February or March for release as yearlings. This procedure was repeated for four years, from 1991 to 1994.

As the marked fish were recaptured in various fisheries, the heads were taken, coded-wire tags removed and decoded, and the data was entered into the PSMFC data base for coded-wire tagged fish. Marked fish entering into the Willamette River Basin were recovered at Dexter Fish Ladder, Willamette Hatchery at spawning, or McKenzie Hatchery at spawning. Snouts were removed and sent to the Clackamas Tag Recovery Station for tag recovery and decoding. Despite the complexities of the design, the experiment was completed with only minor problems. One of the worst of these was that El Nino conditions occurred throughout the time of the releases. In spite of the lowered yields, we could make some definite conclusions:

1) Increased rearing densities in a surface water hatchery can result in increased production of adult chinook salmon (Figure 1). Numbers of adults salmon recovered from rearing densities three times that normally used at Willamette Hatchery showed significantly more spring chinook salmon recovered than numbers from control raceways reared at normal densities, either with or without oxygen. However, the efficiency of rearing at high densities was not as good as with normal rearing densities. Percent returns (the number of adults returning per hundred juveniles released) were inversely related to rearing density. This result has been demonstrated in a number of other studies (Ewing and Ewing 1995).

2) Baffled raceways produced smolts with very poor survival. The reason for the poor survival is unknown, although it was found that fish in these raceways had higher metabolic rates than fish reared under comparable densities or loads (kg fish/gallon per minute flow).

3) Ammonia was not a limiting factor at increased densities. As ammonium ion concentrations increased in response to increased density, pH decreased from carbon dioxide excreted. The decrease in pH suppressed the toxic gas, NH_3, in favor of the nontoxic ion, NH_4^+. This decrease in pH occurred because the surface water supply to Willamette Hatchery is low in carbonate ions and consequently low in buffering capacity.

4) Cost benefit ratios have not yet been calculated for the increased numbers of spring chinook salmon resulting from increased densities. However, several modifications which became available after the experiment was initiated may serve to bring costs down in future rearing scenarios. One is the availability of oxygen generators which are very cost effective for long-term rearing. A second factor is the programming of oxygen use so that high density raceways could have oxygen delivered only when the oxygen demands become high in late stages of rearing.

In conclusion, the use of oxygen supplementation for rearing increased densities of spring chinook salmon has demonstrated that the number of fish returning to the facility can be increased with minor modifications to existing raceways. This should provide a means for increasing production without the huge capital expense of building new raceways.

References

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Table 1. Characteristics of experimental ponds at Willamette Hatchery.

Group Designation	Characteristics
A	Normal density, no oxygen supplementation
B	Half density, no oxygen supplementation
C	Normal density, oxygen supplementation
D	Triple density, oxygen supplementation
E	Michigan system, first pass, oxygen added
F	Michigan system, second pass, oxygen added
G	Michigan system, third pass, oxygen added

Group	Number of fish	Final kg	Inflow Lpm	Load kg/Lpm	Pond volume m^3	Density kg/m^3
A	36,000	1,633	1895	0.86	104.8	15.58
B	18,000	817	1895	0.43	104.8	7.80
C	36,00	1,633	1895	0.86	104.8	15.58
D	108,000	4,899	1895	2.58	104.8	46.75
E	54,000	2,449	2843	0.86	52.4	46.75
F	54,000	2,449	2843	0.86	52.4	46.75
G	54,000	2,449	2843	0.86	52.4	46.75

Figure 1: Average Number of Returning Adults, 1991 - 94 Releases

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MONITORING, EVALUATION AND MANAGEMENT: AN ESA CONNECTION

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Abstract

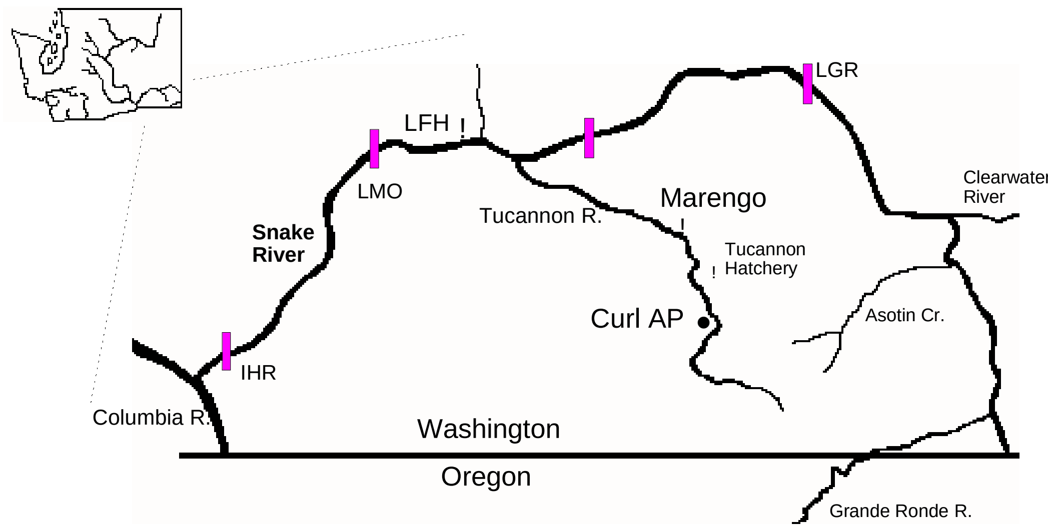
Snake River sockeye, spring/summer and fall chinook salmon, steelhead and bull trout have been listed under the Federal Endangered Species Act (ESA) to protect and recover those populations from perilously low levels. The ESA, while encumbered with process and paperwork, retains as its central theme a reestablishment of healthy, self-sustaining populations of fish and wildlife within the U.S. For most fish populations, significant changes in their habitat and/or their management must occur before progress toward stable healthy populations can begin.

Understandably, management agencies faced with implementing change must ensure that actions taken are biologically sound and supportable, or at least, that actions have a reasonable chance of reducing negative effects of a condition on the listed species. Unfortunately, agencies such as Washington Department of Fish and Wildlife (WDFW) and federal wildlife management agencies are frequently faced with making decisions about the management of listed species without all the data and knowledge they need. Within the Snake River basin however, the presence of a Monitoring and Evaluation (M&E) study group associated with the Lower Snake River Compensation Plan (LSRCP) hatchery mitigation program has allowed WDFW to respond to the ESA management challenge in a timely fashion.

Background

During the 1970's the states of Oregon, Washington and Idaho, and the U.S. Fish and Wildlife Service negotiated with other federal agencies such as the Corps of Engineers (COE) to mitigate for adult fish losses to anadromous populations caused by construction of the four lower Snake River power dams. The Lower Snake River Compensation Plan (U.S. Army Corps of Engineers 1975) was the result of those negotiations. Hatchery production was considered the most efficient means to replace lost resources, and in Washington, Lyons Ferry Hatchery (LFH) on the Snake River (RM 58) was constructed and the Tucannon Hatchery (RM 36) renovated as the core of the mitigation program (Fig. 1). Washington's anadromous portion of the program was to mitigate for 18,300 fall Chinook, 1,152 spring Chinook, and 4,656 summer steelhead. Additionally, 87,000 pounds of rainbow trout were to be reared to provide resident fish angling opportunity in Washington and Idaho. The Tucannon River is a major Snake River tributary in Washington which receives LSRCP spring chinook salmon, summer steelhead and rainbow trout mitigation, and will be the focus of this discussion.

Figure 1.



At the time of the 1991 and 1992 listings of Snake River sockeye and spring/summer chinook under ESA, WDFW was annually releasing 160,000 steelhead into the Tucannon River, the majority of which were acclimated in Curl Lake (RM 41) Acclimation Pond (AP) on the Tucannon River prior to release. Coded wire tag (CWT) studies demonstrated that releases were marginally successful, but still less than the LSRCP goal. WDFW wanted to maximize smolt survival, emigration success, and adult return to meet mitigation goals in an efficient manner.

A 1991-93 M&E study showed that up to 66% of juvenile fish in the AP were not fully smolted, and that 10.3% - 17.7% residualized (failed to migrate) in-river (Schuck et al. 1994). Furthermore, juvenile steelhead which residualized in the river, closely resembled juvenile steelhead which failed to exit the acclimation pond during a six-week volitional emigration period (non migrants). Also, a comparison of adult returns from the 1991-1993 AP released steelhead, to adults returning from direct releases adjacent to Curl Lake AP for the same years, showed that the direct released fish returned at a much greater rate (Schuck et al. 1995). These data caused managers to question acclimation pond use as an effective management tool.

To fully assess acclimated vs. direct released fish performance, M&E staff began a new study in 1994. The study would; 1) determine why the Curl Lake AP release was not performing as effectively as other LSRCP steelhead releases in Washington, 2) try and characterize what constituted a successful smolt using new tag technology, 3) determine if unsuccessful (non migrating) fish could be separated from migrants using the acclimation pond, 4) help identify ways to minimize the potential effects (residualism, predation, competition) of hatchery steelhead releases on wild juvenile salmonids, and 5) determine whether non acclimated direct releases of steelhead near Curl Lake AP and further down-river could survive equally or better than acclimated releases. Results from the 1994-1997 study are summarized here.

Methods

Passive integrated transponder (PIT) tags and CWTs were used to characterize successful migrants. PIT tags represented new technology in 1994 that allowed individual fish to be accounted for after their release. Pre-release or at-release data for each fish could then be ascribed to successful or unsuccessful fish. A study fish was considered to be successful if it was detected downstream of its release point at one of the Snake or Columbia River PIT tag detector dams.   Adult survival success (measured as smolt to adult survival (SAR) percentage) was calculated from CWT returns to the Snake basin fisheries, hatchery recovery and escapement as estimated through spawning surveys.

Study groups received a CWT and fin clip 8-9 weeks before being placed in Curl Lake AP, and up to three months before being released directly to the river. All tag groups were held in raceways at LFH for at least 14 days prior to release or transfer, and tag retention determined. CWT tagged and untagged fish within Curl Lake AP contributed to all PIT tag groups. All direct stream releases were 100% CWT, therefore no untagged fish could be PIT tagged for those study groups.

Pond emigrants and juvenile steelhead which failed to exit the acclimation pond, (behaviors which had been observed in the 1991-93 study) were PIT tagged from Curl Lake AP in April and May of the 1994-1997 migration years. Three groups of approximately 115 migrant fish (fish trapped as they left the pond voluntarily) were PIT tagged over a six-week migration period. Fish were netted, anesthetized with MS-222, tagged, weighed, measured, classified (smolt, transitional smolt, parr or precocious male), allowed to recover and then immediately released. The non migrant group consisted of fish which failed to leave the pond after the six-week voluntary emigration period. Three hundred-fifty fish were netted from the pond, PIT tagged in an identical fashion to migrant fish and released into the Tucannon River at the outlet of Curl Lake AP.

PIT tags were detected at down-river dams fitted with PIT tag detection equipment. Unique detections of PIT tags were used to determine success. Multiple detections of a single tag at one or different dams were not counted. Length, weight, condition factor and classification for each detected fish were from date of tagging, not date of detection. Data summaries therefore represent what a fish “looked like” while still in hand at time of release. In addition to Curl Lake AP tag groups, releases of non acclimated steelhead from LFH occurred at LFH and at Marengo (RM 21) on the Tucannon River (Fig. 1) during the last three years of the study.

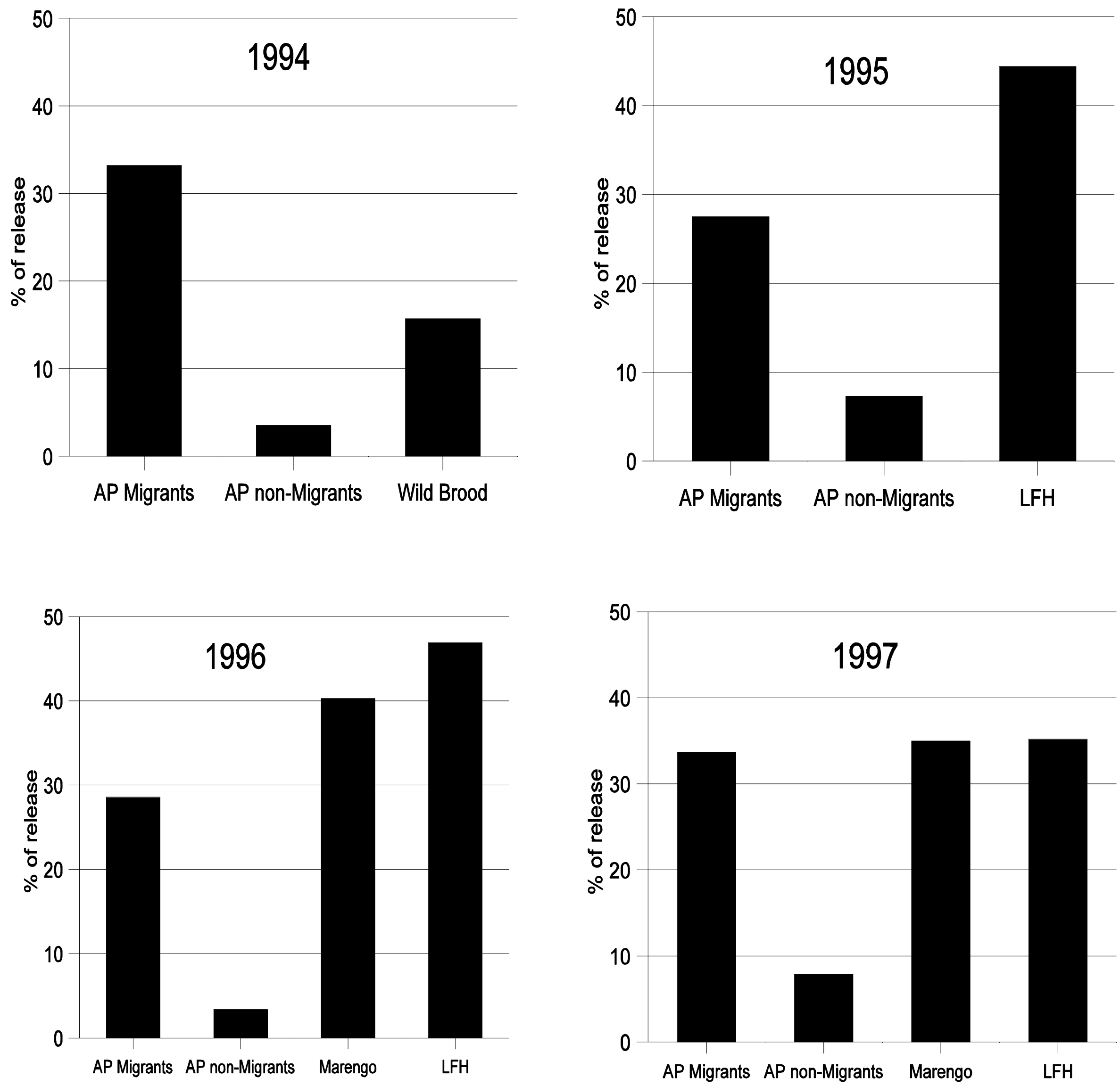


Figure 2. PIT tag detections at Snake and Columbia River dams for Acclimation Pond (AP) and direct releases into the Tucannon River and from LFH, 1994-1997.

Results

There was a 10-fold difference in detections between the AP migrants, and AP non migrants PIT tagged in 1994 (Fig. 2). A release of hatchery reared wild origin Tucannon River steelhead were detected intermediately to the other groups, but this release was not repeated for the duration of the study. Rather, during 1995 a release from Lyons Ferry Hatchery was substituted as a control to which other releases could be compared. Once again a significant (P<0.001) difference in detections between AP migrants and AP non migrants was observed, although not to the extent documented in 1994. Interestingly, detections of the LFH-released group were statistically greater than for the migrant group, and far exceeded detected fish from the non migrants (Fig. 2). Because of increasing concern about the effect of any residual hatchery steelhead on a wild spring chinook, the study was modified in 1996 to include a direct release of steelhead near Marengo (Fig. 1). This area of the river is seldom utilized by spring chinook salmon for spawning and rearing, and results from the earlier study strongly indicated that direct releases into the river at Marengo had been successful in returning adults for the program. Further, direct releases of steelhead at or below Marengo were considered an acceptable alternative to acclimation and retention of potentially residual steelhead by NMFS in their Biological Opinion. Also, WDFW desired to repeat releases conducted in the 1991-93 study, and assess direct releases into habitats below most natural salmon/steelhead production as an alternative to acclimation. Once again, 1996 detections of AP migrant fish far exceeded detections of AP non migrant fish (Fig 2). Detections of fish released from LFH were similar to that observed in 1995, greater than either AP group. Interestingly, detections of fish released at Marengo nearly equaled the LFH group and were significantly greater than the AP migrant group ($0.001<P<0.005$, $\propto = 0.05$). Results from the 1997 migration year were nearly identical to the previous three years for the AP groups: detections of PIT tagged migrant steelhead were significantly greater than non migrants. However, there was no statistical difference between detection of AP migrants and releases from LFH and at Marengo in 1997 ($0.90<P<0.75$, $\propto = 0.05$).

Further results from the study provided a characterization of successful out migrants that was consistent for the four years. Those results showed:

1. Successful fish (regardless of the group) were longer, leaner and more smolted than unsuccessful fish, or the pond average just prior to release (Average successful smolt = 3.8-4.0 fpp; 224 mm; K=0.95).

2. No parr or precocious males were ever detected at downstream dams during the study.

3. During the study, 5-14% of the pond's population did not emigrate from the pond, and only 7-9% of AP non migrants were classified as smolts. It was concluded that pond retained smolts would have out migrated if given a chance, based on the small number of PIT tag detections for AP non migrants groups in each year of the study. These fish represented the cost of operating the pond to retain potentially residual juvenile steelhead.

4. Retaining non migrants in the pond decreased the incidence of residuals' in-river (Viola and Schuck 1995).

5. Smolt to adult return rates for downstream releases were consistently higher than for pond releases (data from 1994-97 study is incomplete).
6. There appears to be a direct relationship between release location and survival success.

Discussion

Results from the four years of PIT tagging provided significant insight to the behavior of hatchery steelhead releases in the Tucannon River. In four of 4 years, AP migrants were more successful than non migrants. Work conducted simultaneously with the tagging study by Viola and Schuck (1995) concluded that retaining non migrants in the AP significantly reduced the number of residual steelhead in the river. This result was fully in line with the NMFS desire to reduce the potential negative effects on juvenile salmon. More interesting however were the results of direct river releases downstream. In two of 3 years, more downstream direct releases were detected (more successful) than pond migrants, and in year three there was no significant difference between AP migrants and fish released directly

The use of PIT tag technology allowed WDFW to more fully understand what constituted a successful smolt. Heightened awareness over ESA listed species, helped to encourage management agencies to act responsibly to recover those populations. Any improvement in the general smolt quality of hatchery fish that results in increased emigration is desirable. An increased out-migration, decreases interaction with wild fish. Results from the study showed that larger, leaner fish which emigrated from the AP were more successful migrants than fish which did not migrate volitionally from the AP.

Early conclusions based on our study results (Viola and Schuck 1995) seemed to support continued use of the AP for steelhead releases, with non migrant fish retained in the pond. Confounding this conclusion, however, were the data for direct releases down-river, which, for the purpose of this study, were remarkably successful. Coupled with the benefits of down river release being outside primary spawning/rearing habitat for spring chinook salmon, and the relative ease of direct releases, it represented an acceptable alternative release strategy in an ESA environment. Regardless of release type, the consistency of data among groups showed that large, lean, smolts were the fish detected as active migrants heading seaward.

Data for SARs for the study period are still incomplete. Preliminary results appear to be following those of the 1991-1993 study (Figure 3) which showed that direct releases of smolts at Marengo and into the Tucannon River at Curl Lake AP, performed consistently better than the acclimated release from Curl Lake AP(Schuck et al. 1997). The data do not support the original management supposition that acclimation of fish prior to release will improve survival and emigration performance. Further, there is no data from either study which suggest that direct releases are straying more than acclimated releases, another presupposed benefit of acclimation.

As a result of the study, Management Biologists made the following decisions/changes in how the program was conducted:

1. Release of steelhead from Curl Lake AP was curtailed. Direct stream releases below chinook rearing areas was begun. This change was supported by the data which indicated that out-migration of direct releases equaled or exceeded AP releases. Further, by moving steelhead releases downstream, most potential negative interactions between them and

juvenile spring chinook salmon were eliminated, a highly desirable end result from the NMFS/ESA perspective.

2. Size at release criteria for LFH steelhead production was modified from 5.0 fpp to 4.0-4.5 fpp, to more closely resemble successful migrants observed in the study. Data collected provided sufficient support for this production change despite concerns expressed by WDFW management and NMFS personnel.

3. M&E follow-up to confirm continued success of hatchery smolts to survive is required.

4. Curl AP was made available for the chinook recovery program under ESA in a critical habitat area.

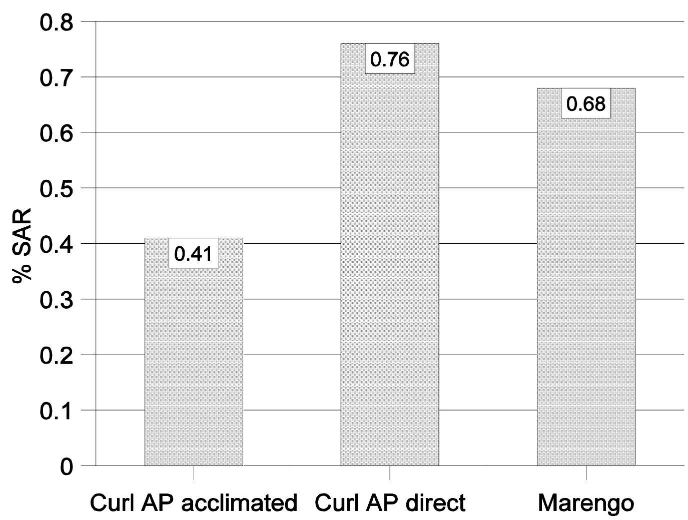


Figure 3. SARs for steelhead releases into the Tucannon River, 1991-93.

Conclusion

The 1994-97 tagging study conducted on Tucannon River steelhead releases provided critical information to management at a critical time. The study was far from classic in its design and completion, and violated some basic tenants of study design that would preclude the acceptance of its results in a peer-reviewed journal. However, the ability of M&E staff to respond quickly to the changing needs of management in an ESA environment, and provide sufficient data upon which reasonable and necessary decisions could be based were invaluable. In the end, wild salmonid populations in the Tucannon River benefitted because of an existing M&E program designed to evaluate a large hatchery program.

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THE KALAMA RIVER WILD BROODSTOCK STEELHEAD PROGRAM: COMPARISONS OF CONTEMPORARY AND TRADITIONAL HATCHERY PRACTICES

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Abstract

WDFW is evaluating the use of wild steelhead as broodstock at the Kalama Hatchery Complex (SW Washington) as part of a multi-year study. Two projects have begun: (1) a winter-run project to compare performance of wild broodstocks in the hatchery to traditional domesticated broodstocks, and (2) a summer-run project to compare the natural reproductive performance of wild broodstock reared in the hatchery to the performance of their wild-reared counterparts. Fecundity of broodstock and survival, growth, and outmigration characteristics of their offspring were compared among 1998 BY winter-run groups. Similar data are being collected from 1999 BY winter- and summer-run fish. Ultimately, smolt to adult return for SR and WR fish and, especially, spawning success of adults from SR smolt plants will be compared to that of wild reared counterparts for three brood years.

Introduction

Studies of steelhead genetics, ecology, and life history have been ongoing in the Kalama River since the mid-1970's. The primary objective of Kalama research to date has been to assess the relative reproductive performance and contribution of hatchery compared to wild steelhead spawning in the wild. For the purposes of this report, wild fish are defined as naturally produced fish, regardless of ancestry, and hatchery fish are those spawned and reared for some portion of their life in the hatchery environment. Earlier Kalama work has shown that highly domesticated steelhead of non-local origin (both summer and winter races) exhibit much lower natural reproductive success than sympatric wild fish (Chilcote et al.1986; Leider et al. 1990; Hulett et al. 1996). This report presents preliminary information on an evaluation of the use of locally derived wild broodstocks (summer- and winter-run) in the Kalama basin.

The use of local wild broodstocks in hatchery programs is receiving considerable attention by WDFW (e.g.,Wild Salmonid Policy [WSP], Steelhead Management Plan, Lower Columbia Steelhead Conservation Initiative) and other agencies responsible for fish management in the Pacific Northwest (NMFS, ODFW, CDFG, IDFG, BCDE). Wild broodstocks are increasingly being used or recommended for use in supplementation applications (intended to increase natural production of depressed stocks) and also in harvest augmentation applications (intended to provide harvest opportunity). Current theory indicates that genetic risks to wild populations might be contained if the degree of genetic similarity between hatchery and wild stocks is high (e.g. Krueger et al. 1981; Allendorf and Ryman 1987; Fleming and Gross 1993). The presumption is that hatchery programs based upon or integrating locally adapted wild fish as broodstock would pose the least risk to wild populations. Alternatively, interbreeding between wild fish and fish domesticated for any number of generations may pose an unacceptable level of risk by causing shifts in genetically based performance traits and affecting survival (Reisenbichler 1996). To date, direct and conclusive empirical evidence in support of either conjecture is lacking. Primary goals of the investigations are to develop wild broodstock steelhead programs, identify risks imposed upon natural production by those programs, and identify strategies to manage those risks.

Methods

Winter-run Project: Three WR hatchery groups were created in 1998: (1) fish from wild Kalama broodstock (KW), (2) fish from the traditional Beaver Creek Hatchery broodstock reared from the fry stage at Kalama facilities (BCK), and (3) Beaver Creek fish reared at the Beaver Creek facility and trucked to an acclimation pond as smolts for final rearing (BCBC). Broodstock for the Beaver Creek groups were adult returns from earlier smolt plants into the Kalama. Race and origin of all spawners was established using run timing, appearance, and presence or absence of fin clips. Juveniles from each group were uniquely marked with blank wire tags, reared, and released from a common rearing pond in the upper Kalama watershed. Similar groups created in 1999 are being reared now.

Sexually mature broodstock were captured as they entered a fishway trap at the Kalama Falls Hatchery (KFH) during the peak run timing of the respective groups and most were immediately live-spawned using the air injection method for females and strip spawning for males. In 1998 the eggs were fertilized following standard hatchery protocols using approximately 5-fish pools for Beaver Creek origin fish and 1:1 spawning for the wild-origin fish. In 1999 all fish were spawned using a partial factorial cross (2 X 2) to increase the effective breeding size of the population (Busack et al. in prep.). Milt was checked for motility before being used to fertilize eggs. Eggs from individual females were incubated separately in shallow troughs or stacks. Fecundity estimates were obtained by counting a weighed subsample of green eggs or by counting eyed eggs and adding back mortalities. After hatch, families were pooled within groups and reared using standard practices for BCK and BCBC fish. A more aggressive feeding regimen including frequent hand feeding and the use of belt and demand feeders was necessary for KW fish. All three groups were wire tagged before transfer in February 1999 to Gobar Pond, an acclimation site in the upper watershed, for final rearing. Wire tags were inserted in different positions so juveniles could be assigned to their groups after pooling. The smolt release was accomplished using a volitional strategy. Rearing fish were sampled monthly to obtain estimates of length, weight, fin condition, and an index of smolt appearance (silver coloration, lack of parr marks, black band on caudal fin). Similar data were obtained on a weekly basis from fish exiting Gobar Pond after active migration began on 5/4/99. Exiting smolts were tagged with photonic tags to allow determination of exit time of migrants captured either in a downstream smolt trap or during sampling for residuals (fish that did not emigrate) in the acclimation pond and in Gobar Creek. The screw-type smolt trap was located at KFH approximately 12 miles downstream from Gobar Pond. Residual fish were enumerated by snorkel survey and sampled by electroshocking and angling.

Summer-run Project: Wild Kalama summer-run steelhead were collected systematically from throughout the run in 1998 and held until spawning in covered ponds at KFH and at the Skamania Hatchery. The broodstock were held at two different facilities to minimize the risk of losing all the fish in any one catastrophic event. Pond covers were constructed of floating PVC frames covered with opaque plastic or netting. The covers precluded jumping and provided hiding cover but still allowed sufficient natural light into the ponds for photoperiod mediated final maturation of the fish. Adults held at both facilities received prophylactic formalin treatments to control disease and were disturbed as little as possible to avoid stress. Broodstock were sorted by sex in December with males sequestered downstream from the females. Females were periodically checked for ripeness beginning in late December, 1998. Spawning was carried out as described above for the 1999 winter-run. The first brood is rearing now and preliminary sampling for growth characteristics follows the methods described above for winter-run.

Results and Discussion

Winter-run Pilot Project: In 1998 a total of 84 Beaver Creek origin fish and 24 wild Kalama broodstock were spawned. Fecundity averaged 4500 and 3200 eggs/female for wild and hatchery WR broodstock, respectively. Fertilization rates (green to eyed eggs) were high (mean 84%) but variable among individual spawners (range 54 to 97%). Green egg to smolt survival was between 60 and 70% among the three groups. Growth trajectories (Fork Length and Weight; Figure 1) were parallel for all three groups but hatchery origin fish were larger throughout juvenile development than the later-spawning (by approximately 3 months) wild broodstock fish. Fish from all three groups exhibited identical changes over time in smolt index (Figure 2). The majority (approximately 80%) of fish from the three WR groups combined smolted and migrated past a smolt trap in the lower basin but apparent residualism of wild origin fish was higher than that of either hatchery origin group (Figure 3). Comparable data are being collected from the 1999 WR brood being reared now.

Summer-run Project: A total of 54 summer-run adults were collected between 5/26/98 and 10/16/98 (Figure 4). For BY 1999 SR, adult survival was greater than 90% over a period that spanned up to 9.5 months (average 7 months). Spawning commenced on 2/3/99 and ended on 4/26/99 with peak spawning in March. Fecundity of the SR adults was 4200 eggs/female, considerably higher than the original estimate of 2600 eggs/female based on earlier work with wild Kalama summer-run. Five adults were released before spawning because the higher fecundity meant adequate numbers of eggs could be obtained with fewer females. Fertilization rates and hatching rates were high overall (88% green to eyed egg survival) but variable among individuals (range 53 to 99%). Green egg to fingerling survival is approximately 84% to date and growth rates are greater than for the comparable WR fish the previous year. Collection of SR broodstock for spawning in 2000 is ongoing with a survival rate at 97% to date.

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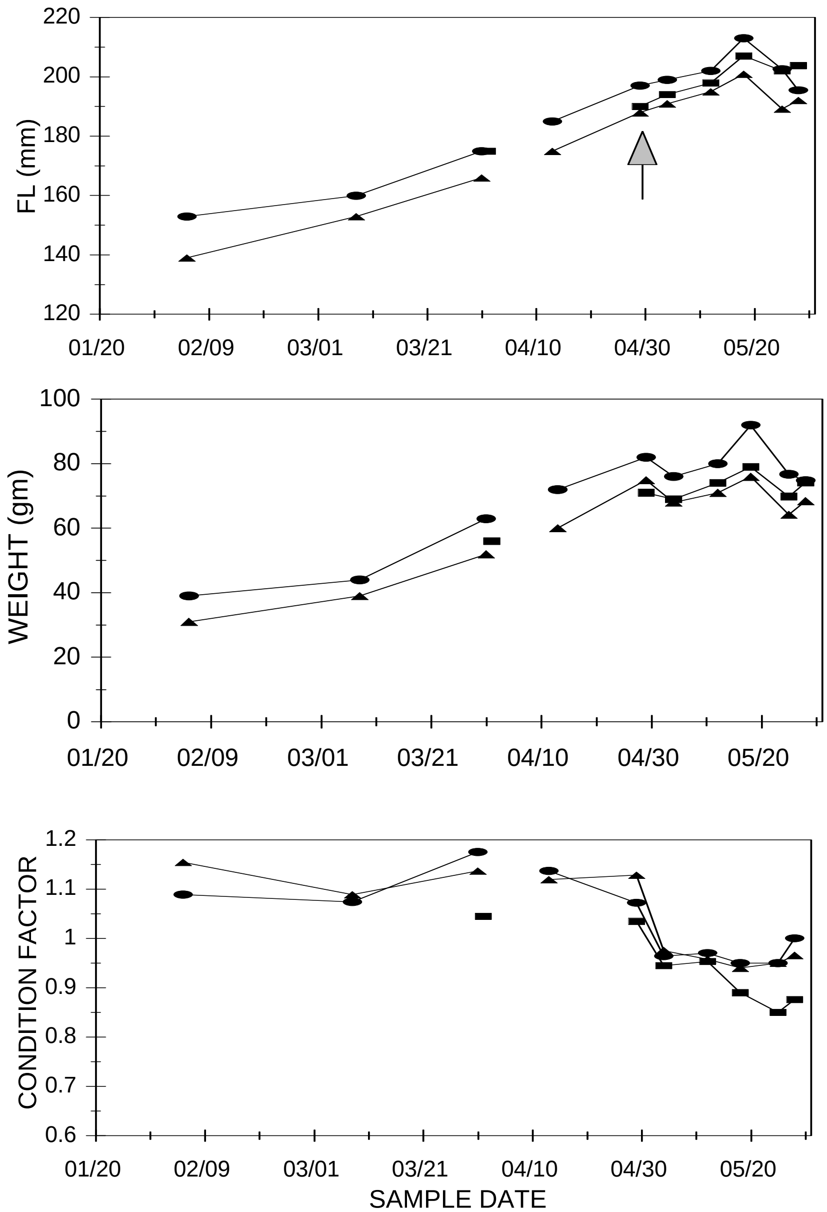

Figure 1. Fork length, weight, and condition factor of BY98 WR steelhead during final rearing and after initiation of volitional release (arrow; top panel). Circles and squares are Beaver Creek origin samples reared at the Kalama and Beaver Creek Complexes, respectively. Triangles are samples from wild broodstock fish.

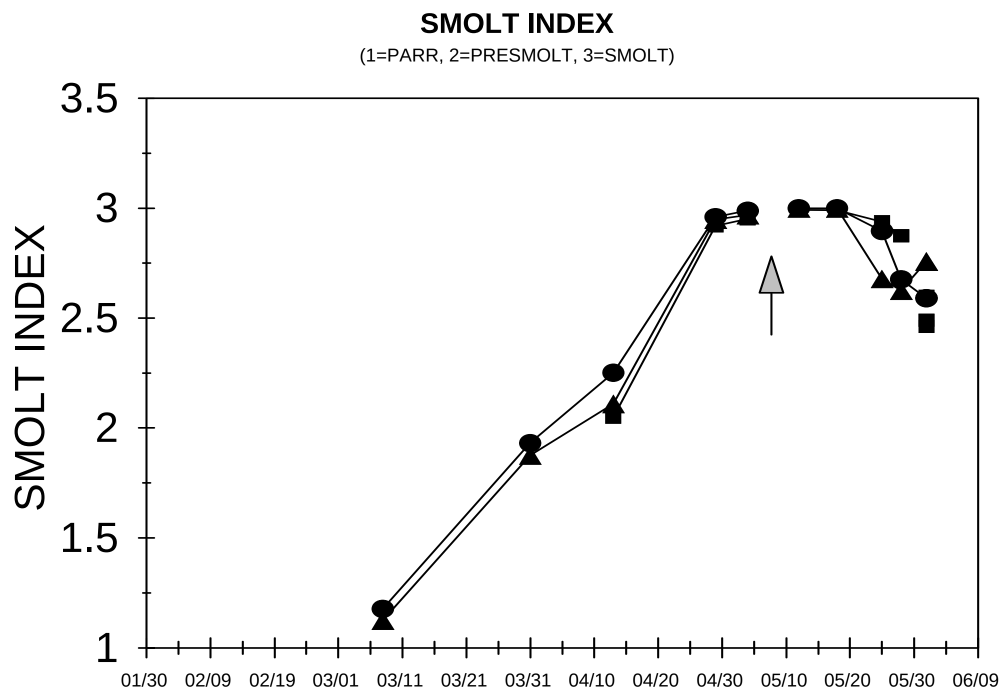

Figure 2. Smolt index during final rearing and release of BY 98 WR steelhead. Circles and squares are Beaver Creek origin samples reared at the Kalama and Beaver Creek Complexes, respectively. Triangles are samples from wild broodstock fish.

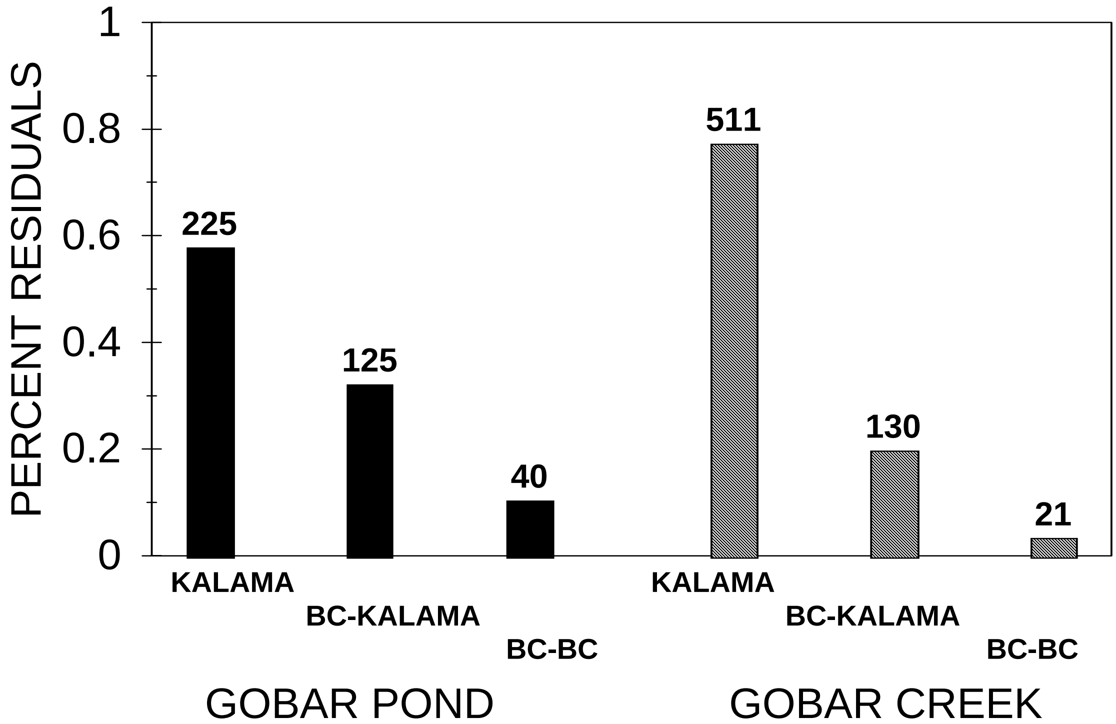

Figure 3. Proportion of fish from three release groups in Gobar Pond at end of volitional release (on 6/1/99; black bars) and in Gobar Creek after 6/15/99 (cross-hatched bars). Kalama, BC-Kalama, and BC-BC refer to wild broodstock, Beaver Creak reared at Kalama, and Beaver Creek reared at Beaver Creek, respectively. Numbers above bars are sample sizes.

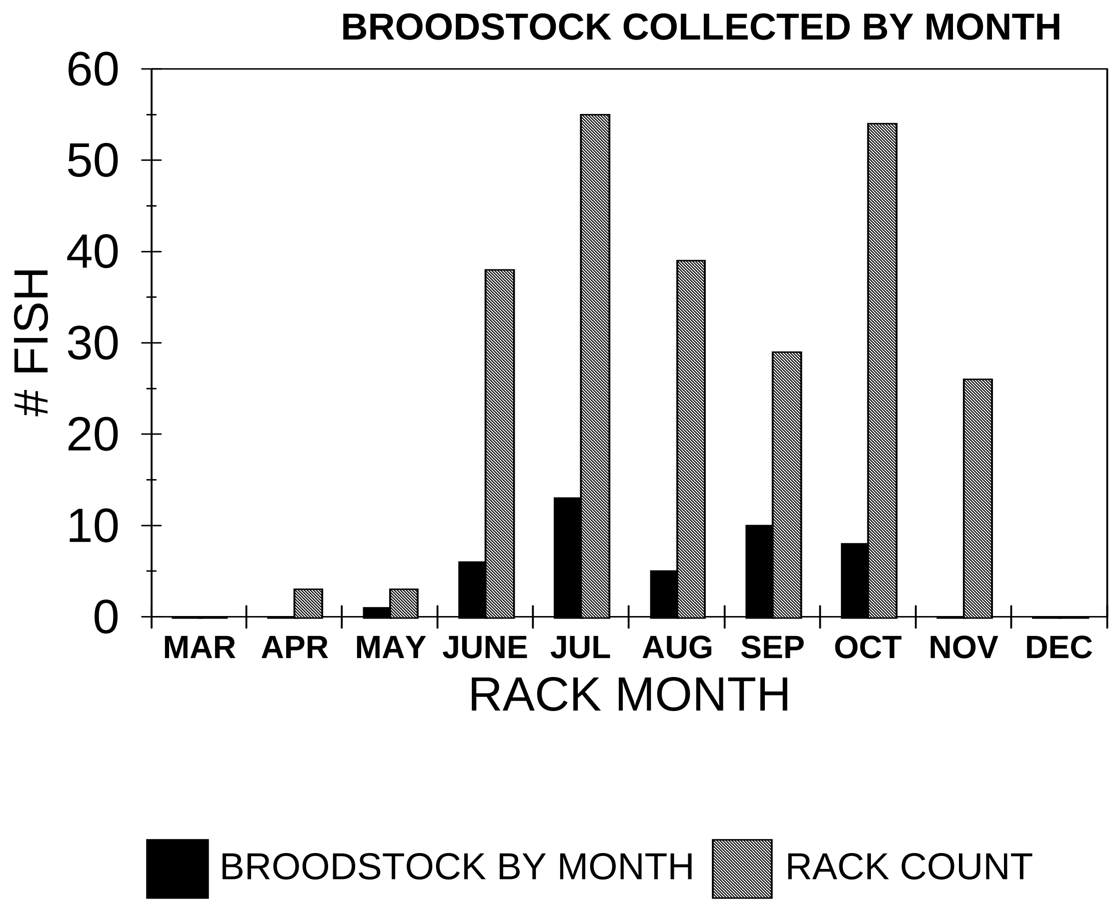

Figure 4. Collection of summer-run broodstock in 1998 (for spawning in 1999) and rack count over the same time period.